

Gemini Planet Imager Observational Calibrations XV: SPIE. Instrumental calibrations after six years on sky



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Introduction

The Gemini Planet Imager¹ (GPI) is a facility instrument of the Gemini South observatory in Chile designed for high-contrast imaging of planetary-mass companions and circumstellar debris disks around nearby young stars. GPI has been in routine operations for the last six years during which time we have been monitoring several aspects of the calibration of the instrument. These are essential for the interpretation of measurements made with the instrument, and for comparisons with results from other high-contrast imaging instruments.

Photometric Calibration

GPI uses a high-order adaptive optics² (AO) system and an apodized Lyot coronagraph³ to enable high-Strehl ratio, high-contrast observations of nearby young stars. Precision photometry and astrometry is complicated by the obscuration of the target star by the coronagraph. To overcome this, a wire diffraction grating was imprinted on the pupil-plane apodizers⁴ to create attenuated replicas of the central star. The flux ratio between these “satellite spots” and the central star is a crucial calibration for determining the absolute luminosity of the planets that GPI images.

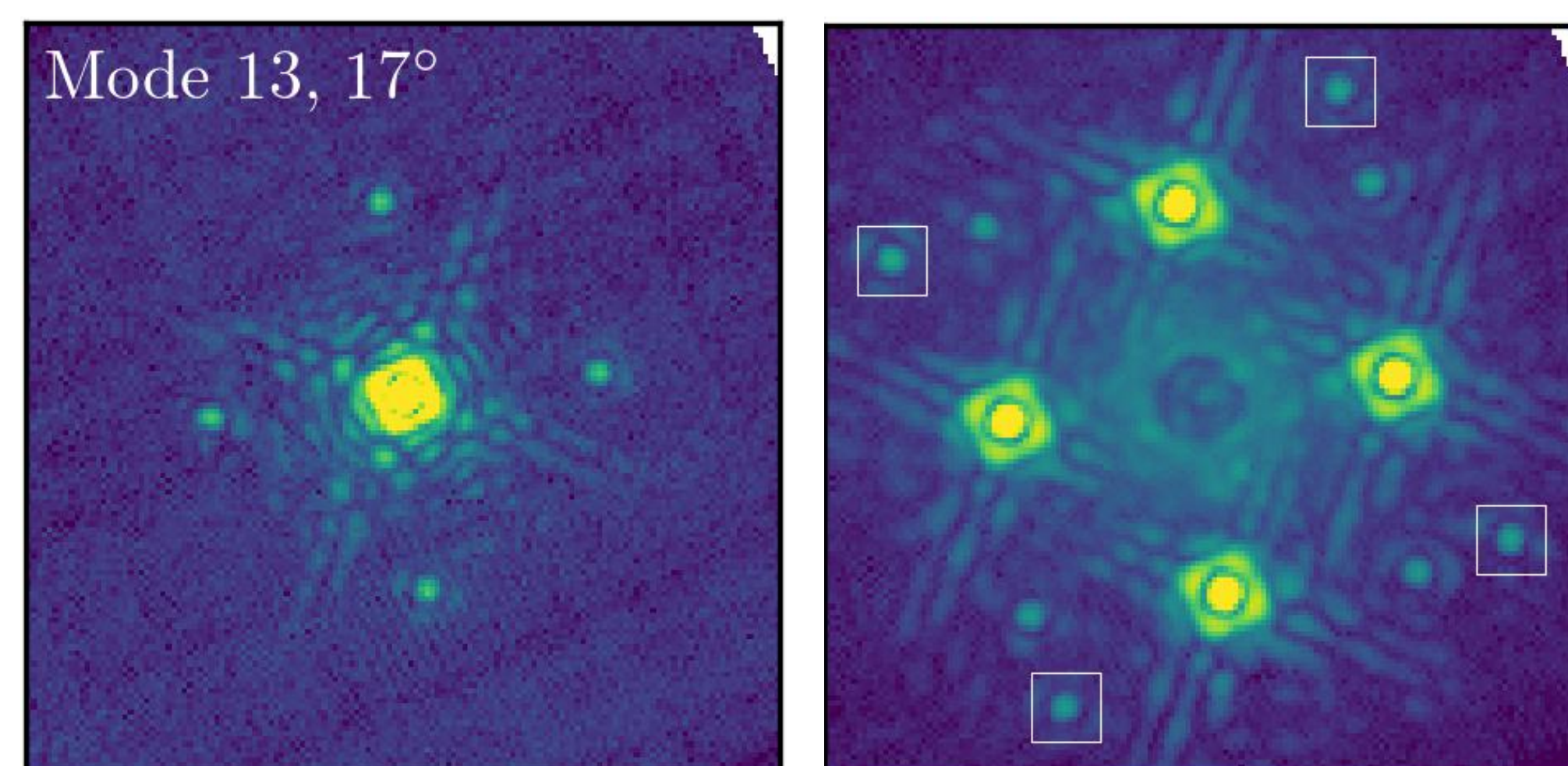


Fig. 1 – (left) Image with the ND filter showing the central source and DM spots. (right) the source is now in the coronagraph and the satellite spots are visible (indicated)

The flux ratio was calculated with GPI’s internal source using a two-step process given the limited dynamic range of the detector. A sine wave applied to the deformable mirror generates additional spots with a 100:1 flux ratio (Fig 1).

Filter	Apodizer	Flux Ratio (x10 ⁻⁴)	Δm
Y	Y	1.60 ± 0.09	9.49 ± 0.06
J	J	1.84 ± 0.08	9.34 ± 0.05
H	H	1.74 ± 0.03	9.40 ± 0.02
K1	K1	2.12 ± 0.13	9.19 ± 0.01

The revised ratios (above) are lower than the previous calibration⁵ for H-band, the most used GPI filter and apodizer combination.

Astrometric Calibration

A precise and accurate astrometric calibration is required in order to convert positional measurements made on the detector into sky-plane separations and position angles. We have identified several pipeline issues⁶ that were affecting the previous calibration⁷:

- Exposure start time calculated incorrectly for coadds
- Average parallactic angle through meridian passage
- A clock drift between the GPI computer and UTC

These all contributed to an error in the calculation of the average parallactic angle of an exposure (Fig. 2), including those used for astrometric calibration.

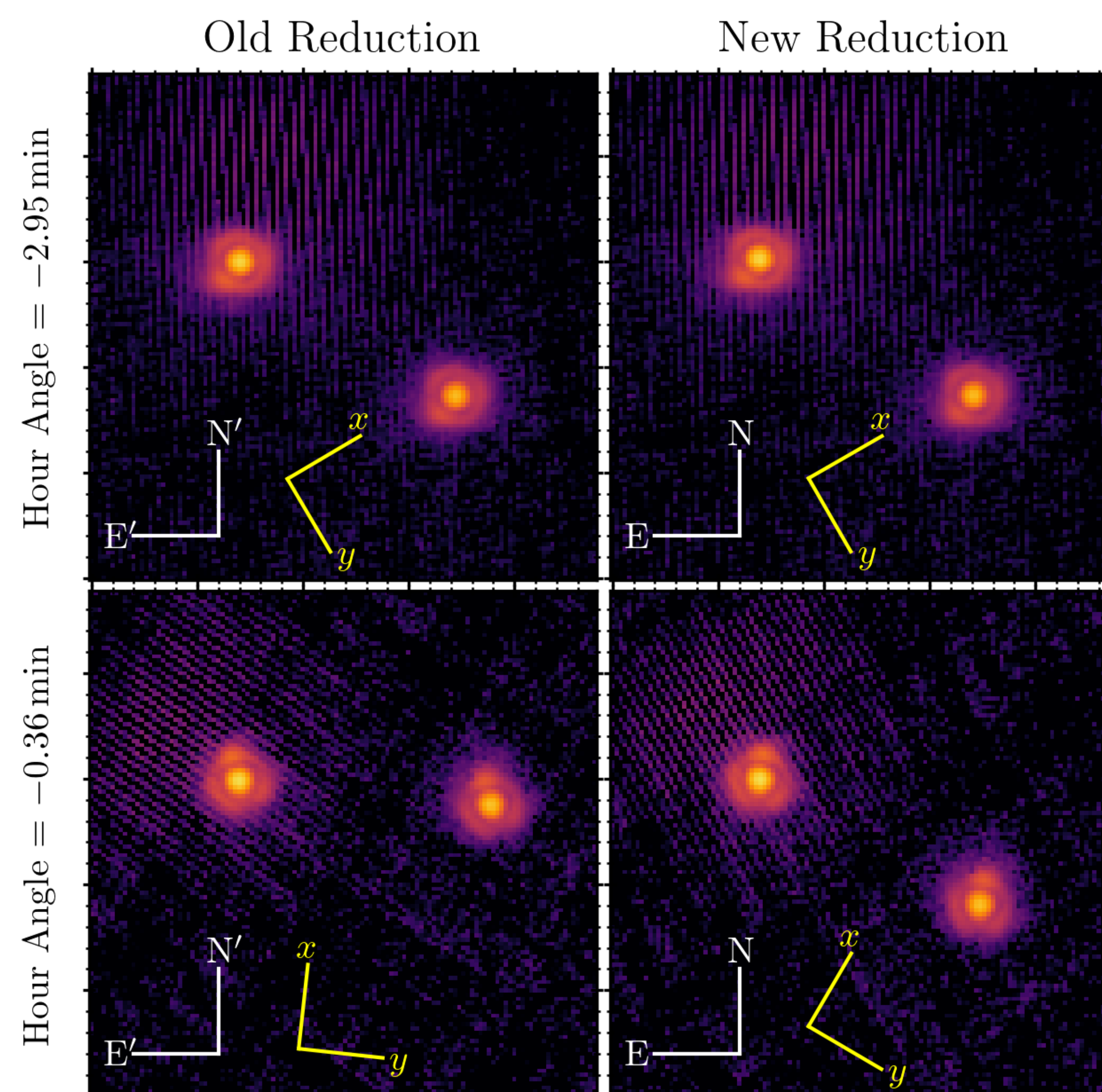


Fig. 2 – Observations of a calibration binary three minutes (top row) and a few seconds (bottom row) reduced with the previous (left column) and current (right column) of the pipeline. With the various fixes to the pipeline the position angle of the binary no longer appears to change as a function of hour angle.

We used the updated pipeline to process astrometric calibration data taken during commissioning, as well as data taken during routine science operations. We measured a detector plate consistent with the previous analysis but find a significantly different (and potentially time-dependent) north offset angle, driven by the fixes to the parallactic angle calculation.

These pipeline fixes have been incorporated into the latest version of the GPI pipeline (v1.5), available on github:

https://github.com/geminipianetimager/gpi_pipeline

Instrumental Polarization

A significant source of noise in reduced GPI polarimetric imaging datasets is the polarization of the instrument itself. The GPI pipeline performs a subtraction of this signal⁸, but the subtraction is imperfect, leaving residuals in the images of the various Stokes vectors. These residuals can be significant for low-surface brightness circumstellar debris disks, complicating the interpretation of their observations.

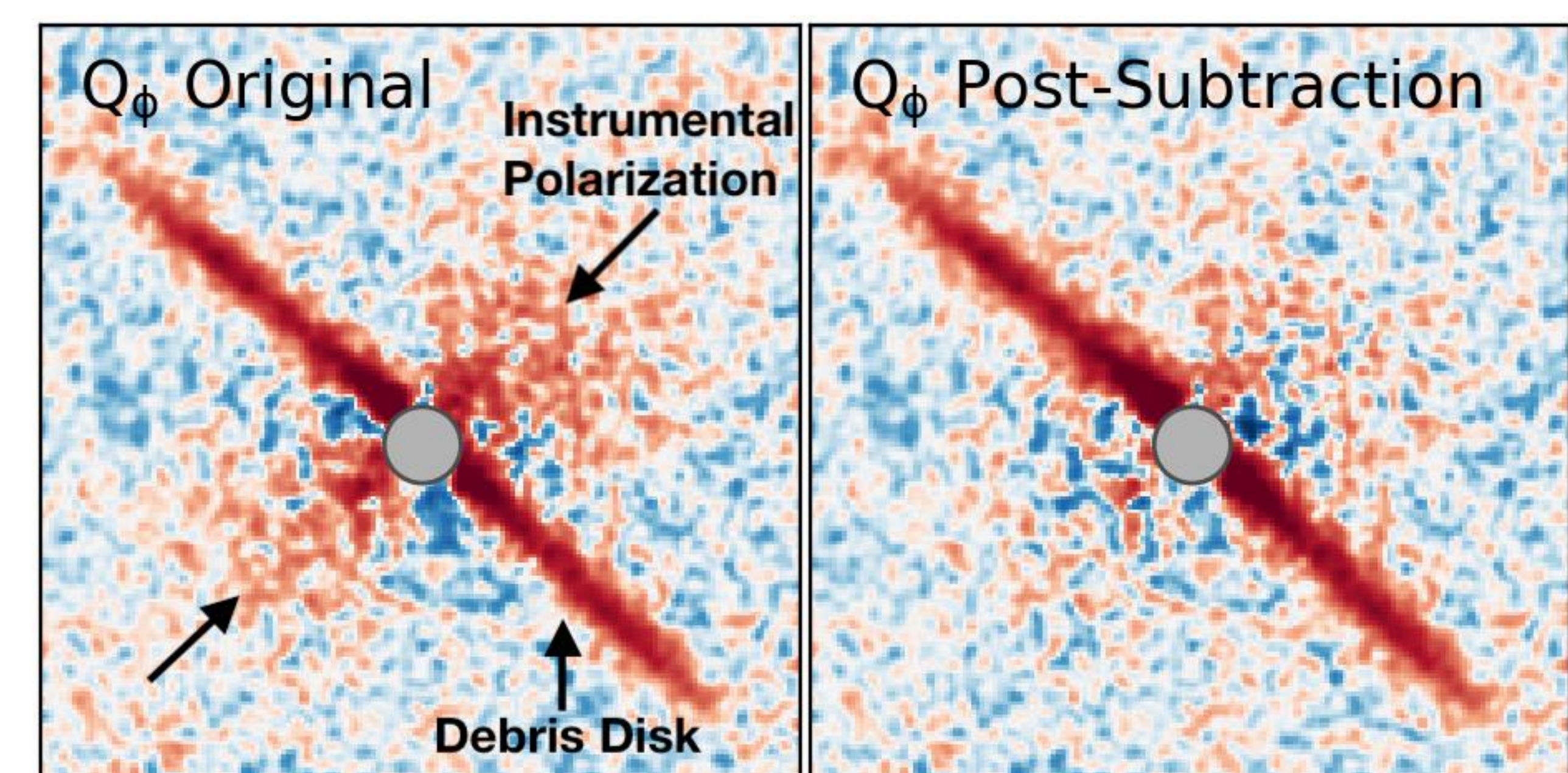


Fig. 3 – Example result of the instrumental polarization subtraction for the HD 32297 debris disk (log scale; blue are negative values). The original image (left) shows a strong residual signature which is more cleanly subtracted with the new algorithm (right).

We have developed a standalone Python script that can be applied to polarimetric datasets reduced with the GPI pipeline to fit and subtract this residual polarization signal (Fig. 3). The algorithm fits for the instrumentation polarization noise across each set of waveplate rotations. We find that this better accounts for changes in atmospheric seeing, AO correction, star centering behind the coronagraph and parallactic rotation. This approach significantly reduces both the low and high frequency systematic noise related to the instrumental polarization.

Conclusions

Continued monitoring of instrument calibration is critical for the interpretation of high-contrast imaging observations, and for comparison with datasets taken with other instruments. We have identified and fixed several issues with the pipeline affecting the instrument calibration and have revised the various calibration values here. We will continue this monitoring effort once the instrument is upgraded and re-commissioned on Geminin North in late 2022.

References

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